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CONTENTS

Instructions in Regard to Preparation of Manuscript: Prepared by a committee for a Conference of Editors of Psychological and Anthropological Journals at the National Research Council, 57.

General Review and Summary:

The Electrical Phenomena of the Skin (Psychogalvanic Reflex): C. Landis and H. N. DeWick, 64.

Notes and News, 120.

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THE
PSYCHOLOGICAL BULLETIN

INSTRUCTIONS IN REGARD TO PREPARATION OF MANUSCRIPT

The Conference of Editors and Business Managers of Anthropological and Psychological Periodicals held in Washington, D. C., November 30th and December 1st, 1928, under the auspices of the Division of Anthropology and Psychology of the National Research Council, adopted the following report of the committee on form of manuscript.

The committee realizes that it neither has, nor wishes to assume, any authority in dictating to authors, to publishers or to editors; but it suggests the following recommendations for use as a standard of procedure, to which exceptions would doubtless be necessary, but to which reference might be made in cases of doubt, and which might be cited to authors for their general guidance in the preparation of scientific articles.

I. *General Form of Manuscript*

a. *Length*

A safe and useful prescription is to be as brief as possible without sacrificing clarity or pertinent facts. Pressure upon space in the scientific journals and the present heavy demands upon the informed reader both reinforce this prescription. Careless writing is usually diffuse, incoherent and repetitious. Careful reading by a competent critic will usually suggest means for reduction. Articles requiring serial publication should ordinarily be published as monographs and not in the journals.

b. *Physical Characteristics of Manuscript*

Most manuscripts suffer many changes by author and editor after they are finally typed. A crowded and untidy page delays both the editor and the compositor, leads to

typographical errors, and increases the expense of publication. A clean manuscript should be sent to the editor. If a minor change is necessary, it may be made by writing between the lines, above the line in which the correction is desired (never in the margin); but it is preferable to rewrite the page. Typing should be double- or triple-spaced, with wide margins. Pages should be numbered in the upper right-hand corner. The writer who is incompetent in spelling, grammar, or syntax should seek help. Authors presenting scientific articles for publication are expected to be literate and self-critical. They should not be surprised or resentful when careless and illiterate manuscripts are declined and returned. A badly prepared manuscript always suggests uncritical research and slovenly thinking. Definite instructions should be given by authors to typists. Authors should always *proof-read* the final typed copy of the manuscript before sending it to the editor. Inserts should be typed on a separate page of the same size as the body of the paper, clearly marked (*e.g.*, an insert to be included on page 25 should be marked *25-A*), and the place for insertion indicated on the manuscript.

c. *Logical Headings; capitals and small letters*

Necessary headings only should be inserted. They should be carefully coordinated. Capitals should be avoided whenever possible, for without them the editor will find it much simpler to make his designations to the printer. Bad practice has tended to an intemperate and unjustified use of capital letters, which increases the costs of printing and disturbs the reader. Short sentences and short paragraphs should be employed wherever feasible. Punctuation in headings should be avoided.

II. *Subdivision and Articulation of Topics*

a. *Introductory Sections*

The introduction should be proportionate to the main body of the article. It should contain a brief concise statement of the topic or problem proposed and of its setting in the literature. If historical, it should refer to all accessible histories but should not repeat their contents. Many articles would never reach the editor if the author knew

what had already been done upon his problem. Experimental articles would often be briefer and more effective if they began where other researches had left off. Many manuscripts on experimental subjects are returned because the authors lack adequate historical knowledge of their topics and do not propose clear-cut problems. Much space in our journals can be saved by better introductory sections.

b. *Main Body of Article*

i. Expository and descriptive articles

Logical progress and coherence in developing the argument are essential.

ii. Critical and argumentative articles

Art is required to re-state, in an objective way, the positions, arguments and results of others. The exposition of an opponent should be clearly separated from the author's own arguments and dissents. Blindly defensive protests, written in deep emotion, seldom edify the reader or promote the reputation of the writer.

iii. Experimental articles

The natural order, generally followed, is:

(1) Statement of conditions (including subjects, observers or reactors, apparatus and set-up),
(2) Course of experiment,
(3) Statement of results, and
(4) Discussion of results and conclusions.

As this part of the article presupposes a reader conversant with the problem and with the experimental methods of research, the exposition should be technical, concise and not repetitive, as well as clear and straightforward. At the same time, the competent reader demands an exposition of details sufficient to enable him to reconstruct and to criticize the experimentation and to compare it with other procedures and results.

c. *Summary*

At the end should be written a plain and brief statement, as categorical as possible, containing nothing not substantiated in the main part of the article.

d. *Abstract*

The author is expected to supply to the editor on a separate page (in triplicate) a brief abstract of his article for

transmission to *Psychological Abstracts* and *Social Science Abstracts.*

III. *References and Footnotes*

a. *Choice of references*

References should be sufficient for the orientation of the article. Only significant titles, none unknown to the author and none for filling, should be included. The author should acquaint himself with bibliographies on related subjects, and should cite them; but he should not duplicate them.

b. *Place of reference in manuscript*

Two forms are commonly used: (1) footnotes, and (2) bibliographical references placed at the end of the article in numerical or alphabetical sequence. Quotations should be included in the page.

c. *Footnotes*

Footnotes should be avoided when the material can be suitably incorporated in the text. When used they should be numbered consecutively throughout the article, and should be typed in their consecutive order separately from the manuscript.

d. *Form of abbreviations*

The form should be as brief as possible without sacrificing clarity and explicit reference. A standardized list of abbreviations will be found in the *Psychological Index,* 1924 (for 1923).

e. *Form of Reference*

The use made of a reference when incorporated in a bibliography is not quite the same as the use of a footnote. The difference is indicated in the following examples:

For footnote:

"[1] C. B. Atwater, Binocular rivalry, *Psychol. Rev.,* 1907, 18, 382–389."

Here the entire reference is blocked in a single sentence; initials first; full title with no caps save for first word and proper nouns (not a universal custom); standard abbreviations for the periodical; the order should be year-volume-

pages, although some editors prefer the volume number before the year, and some prefer it before the periodical.

For bibliography:

"1. Atwater, C. B. Binocular rivalry, *Psychol. Rev.*, 1907, 18, 342–389."

Here the author's name is set off by a period and alphabetically arranged with others.

The same difference may be observed in book titles, *e.g.*,
For footnote:

"[1] S. Eldridge, The organization of life, New York, Crowell, 1925, 70–71."

For bibliography:

"1. Eldridge, S. The organization of life, New York, Crowell, 1925, pp. 70."

f. *Repetition of reference*

Full name and initials should always be cited in references. The following abbreviations should never be used by the author; *loc. cit.*, *ibid.*, and *op. cit.*

g. *Titles*

The title of the article should be brief and explicit. Subtitles may be used.

IV. *Tabular Matter and Illustrations*

a. *Tables*

Tables are expensive, hence they should be as few and as simple as possible but sufficient for the reader to deal critically with the results. Often two or more tables prepared for the author's use may be combined by him into one and greatly simplified. Penciled lines may be inserted wherever necessary to prevent ambiguity in spacing. (Authors will do well to examine the usage of carefully edited journals in the various sciences. Inexperienced writers should seek aid in the preparation of tables.) In preparing long tables the author should consider the dimensions of the printed page. Every figure and every computation should be proved beyond the possibility of error. Column-headings should be brief and unambiguous and should be adjusted to column-width. The tables should be headed thus: TABLE 1,

TABLE 2, etc. Each should have a concise but adequate caption.

b. *Illustrations*

Many scientific journals call all illustrations "figures." The designation is made below the cut, graph or drawing, in arabic characters, thus: Fig. 1, Fig. 2, etc. Some editors retain the term "plates" for half-tones. This usage seems to have come from the practice in certain sciences of inserting plates on special paper at the end of the issue or volume. The use of "figures," involving only one numeration for the illustrative material, would seem to be most easily followed by the reader; but wherever it is necessary to place illustrative material on separate sheets in the volume they may be called "plates" and numbered consecutively. All figures should be prepared exactly as they are to appear in in the text, save in size. A desirable size is twice that in which the author expects the figure to appear; although further reduction is sometimes necessary. Scale of reduction desired by the author should be indicated. All letters and drawings for reproduction should be made with India ink, in heavy and accurate lines on tracing paper, cloth, or heavy drawing paper. Blue lines do not reproduce, and other colors do not reproduce well. Photographs should be as simple as possible, with strong lines and contrastive shading, and should include only the essential parts of objects, apparatus, and the like. Portraits should generally be excluded from set-ups. Line-drawings and graphs should be simple, precise and accurate, with lettering and brief descriptive terms and designations included whenever possible within the limits of the figure, but never in the margin. Coordinate numbers at base and side of the graph form a part of the figure. If gummed letters and digits are used, they should be firmly and neatly glued to the paper. The figure may be kept simple and clear by explanations typed below. Authors should seek expert guidance in these matters. The name of the figure is generally typed below; *e.g.*, "Fig. 3. Instrument for observing ocular movements." Drawings and photographs together with accompanying lettering should be twice (at least) the size in which they are to appear on the page. All drawings should be wrapped

flat against stiff cardboard or rolled on tubes with the greatest care when sent to the editor, in order to protect them against defacement and folding. Where authors supply electrotypes or line-cuts, these should be carefully packed and shipped to prevent defacement. Clips should not be used to attach drawings or photographs to titles, nor should there be writing on the back. All legends should be typed separately from the manuscript and numbered to correspond with the figures. The author should clearly indicate in the legend and in the margin of the manuscript *page the exact position in the text of each table and figure.* Remember (1) that illustrations are designed to serve the reader, not to sustain the author's own memories of his research; and (2) that the journals are limited by space and by cost. All illustrations are expensive. Limit their number and their size as far as is possible.

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THE ELECTRICAL PHENOMENA OF THE SKIN (PSYCHOGALVANIC REFLEX)

BY CARNEY LANDIS AND HENRY N. DEWICK
Wesleyan University

I. HISTORY

It is commonly stated in the literature that Féré in 1888 was the first to demonstrate the psychogalvanic reflex, but the following quotation from Vigouroux (3), who himself published work on the subject before Féré, shows clearly that this phenomenon was known previous to that date: "The knowledge of bodily electrical phenomena is not new. Since Bertholon, who published in 1786 a treatise in two volumes on '*L'électricité du humain corps,*' the electrical tension of the skin has been a favorite theme of numerous authors. Among others, Péteten of Lyon in his '*Traité d'électricité animale*' (1828) explained by the modifications of the electrical state of the skin certain facts very similar to those which have been described recently, under the name of the action of medication at a distance and the efficacy of the electrical machine in the neuroses. Coudret, in his work of the same title (1834), based an entire therapeutics on this idea." . . . "In 1861, Meissner published in the *Zeitschrift für rationelle Medicin* an account of the electrical condition of the skin." . . . "Finally, M. Stein, of Frankfort, has published in the *Centralbl. f. Nervenheilk.* (1880) a study of the positive tension of the human body."

In 1879, Vigouroux (2) called specific attention to the variations and variability of the electrical resistance offered by the human body and suggested that they might be due to sensitivity, vascular tonus, to the amount of liquid conductor in the tissues, or to the state of nutrition of the parts involved. He further noted that it is necessary to state exactly the strength of the applied current, the sort of galvanometer used, and the units of measurement. In another article of the same date, Vigouroux (1) suggests that variations in bodily resistance are due to the vascular tonus controlling the liquid conductors of the system. In 1888, Vigouroux (4) published the results of a study of electrical resistance as a clinical sign and concluded that the resistance of the human body is part of the vasomotor system

and is valuable as a method of diagnosing certain diseases. Féré, in 1888 (1), first called especial attention to the relationships between affective variations and changes in bodily resistance. He stated that the electrical tension and the intensity of the discharge is augmented under the influence of the moral emotions. In another article, Féré (2) says that variations in the electrical resistance of the body are coincident with the plethysmographic curve and that all of his experiments verify the hypothesis that the diminution of electrical resistance goes with increased irrigation of the tissues.

Tarchanoff, in 1890, studied the effect of various sorts of stimulation, particularly affective or emotional, with respect to the electrical reactions of the human skin as shown by variations in the electromotive force set up. Tarchanoff found that all mental functions are psychogalvanically active and that regions rich in sweat glands give relatively larger deflections than those poor in sweat glands. Tarchanoff attributed this electrical change to the secretory activity of the sweat glands.

After Tarchanoff there seems to have been no work published on the subject until 1897, when Sticker, who was searching for a method of objectively demonstrating sensory disturbances, found as intense deflections from parts of the skin which were anesthetized as from sensible areas, which was contrary to Tarchanoff's secretion theory. Sticker suggested that the current produced is a complicated phenomenon in which the psychic excitement and the current of secretion influence the capillary system of the body in general and that all these factors together constitute the make-up of the phenomenon.

In 1902, Sommer (1), in a study of the electromotor reaction from the fingers, says that Tarchanoff's secretion theory cannot explain all of the observations and that one must also consider a physiological component due to muscular activity. According to Sommer, when solid electrodes are used the oscillations of the galvanometer mirror are occasioned by differences in the pressure of the fingers on the electrodes due to involuntary nervous contractions. In his further work on the subject, Sommer (2, 3) admits the value of all previous theories concerning the cause of the phenomenon but says that they are not complete theories because they do not explain the whole phenomenon. In 1904, E. K. Müller (1, 2) published two articles concerning this phenomenon, using normal, psychopathic, and hypnotic subjects. Finally, Veraguth (1), in 1906, began his work on what he called the " Psychogalvanic Reflex " and in 1909 published a book

under that title. Veraguth's work has served as a starting point for almost all subsequent experimentation in this field.

II. Methodology

A. Circuits.—There are several electrical circuits which have been used in investigating the electrical phenomena of the skin. R. Vigouroux (3) demonstrated the electrical tension and variation in resistance in three ways: (1) by an electroscope, (2) by Leyden jar condensors, and (3) by the use of a capillary electrometer. In his later work Vigouroux (4) used the method of Féré, who first made use of the Wheatstone bridge. Féré (1, 2) found that by using a Wheatstone bridge in a circuit with the subject as the unknown resistance, he could measure the resistance of the human body and compensate for variations in resistance by varying the resistance of the bridge, so bringing the galvanometer needle to a convenient zero point.

Otto Veraguth (1, 2), disregarding the Wheatstone bridge, used one of the circuits originally used by Vigouroux, namely, placing the subject in the circuit with a shunted galvanometer and two Leclanché cells (2.4 volts). This circuit is usually regarded as unsatisfactory, for, although it is very simple, it can only be used for gross qualitative analysis, on account of its technical limitations. Wechsler (3) points out that this method assumes that the resistance of the body remains constant, while, on the contrary, it is sure to vary in an unpredictable manner.

Tarchanoff, in 1890, was the first to use a method in which no ectosomatic current was employed. He measured, not the apparent changes in bodily resistance, but the actual electromotive force of the body. If this method is used the phenomenon is much less marked and consequently it is essential that a sensitive galvanometer be employed.

Godefroy (1), in 1920, published a new and convenient method of demonstrating the psychogalvanic reflex. The author has named this circuit the electrotachographical method, and the phenomenon itself he calls a psychoelectrotachogram. The new feature of this method is the introduction of a transformer in the Veraguth circuit, the subject being connected with the primary coil of a one-to-one transformer and the galvanometer to the secondary coil. According to Godefroy (2, 3), when this circuit is used one obtains the psychogalvanic reflex records showing only actual alterations in the electrical flow through the body. This has the advantage of being more

stable, and requires no preliminary adjusting or pulling back to zero after a reaction, for it returns to absolute zero by itself, thus making possible direct comparison of successive responses.

Gildemeister (4) has described a circuit by means of which simultaneous records of "true" resistance and of polarization may be obtained. Salomonson (1) and Thouless (2) have reported different circuits for the same purpose.

Wechsler (2) has described a method by which all the apparatus necessary to carry out the psychogalvanic experiment is enclosed in a portable box. It contains a d'Arsonval galvanometer together with a clockwork mechanism for unrolling sensitive paper so that photographic records of the galvanometric deflections can be made as they occur.

B. Galvanometers.—For the most part, moving coil (mirror) galvanometers have been used in the investigations of this phenomenon. Vigouroux (3) and others have made use of the capillary electrometer, and a few investigators, namely, Darrow, Einthoven and Roos, Gregor (2), Orbeli, Philippson and Menzerath (1), Richter (1), Salomonson (1, 2), Wechsler (3), Syz (1, 2), and Jeffress have at times employed string galvanometers. Whether mirror or string galvanometer is used seems to make very little difference in the results obtained.

Kübler suggests several methods for eliminating accidental errors in the form of the galvanometric curve, and points out that the quality of the galvanometer which is used is of the utmost importance.

C. Electrodes.—The question of electrodes which are to be attached to the skin is a point of primary importance and of extreme controversy. Vigouroux (3) used platinum electrodes, while Tarchanoff used tubular clay electrodes connected with the skin by hygroscopic cotton pads saturated with saline solution. Fürstenau, in 1906, instead of using two equal electrodes of the same substance, held that it was much better to use electrodes of different material (*e.g.*, copper and platinum), as one then sets up a miniature battery with the current flowing in one direction, so causing larger deflections of the galvanometer. Féré, like all too many other investigators, fails to mention the type of electrodes that were used in his experiments. Although Gregor and Gorn used zinc and carbon electrodes they concluded that such electrodes permit the sweat glands to play a large part in the reaction. Consequently these two experimenters decided in favor of liquid electrodes, so eliminating to a large degree such difficulties as variations of contact, pressure, and movements of the

subject. Abbot and Wells varied their electrodes according to the demands of the experiment and the responsiveness of the subject. Darrow makes use of zinc plates. R. Sommer (2) used inflated rubber membranes covered with tinfoil for electrodes. Other electrodes which have been used include platinum hypodermic needles, by Sidis and Nelson; "liquid," by Sidis and Kalmus, and others; various kinds of solid electrodes, such as brass, zinc, copper, tin, bronze, etc., by Sommer and Fürstenau, and others; Ostwald's normal calomel electrodes by Starch, Fauville, Jeffress, Philippson and Menzerath (1), and Wells and Forbes; glass electrodes filled with saline solution of zinc sulphate, by Densham and Wells (3), Belouss, Ebbecke (5), Kohlrausch and Schilf, and Schwartz (2); an inverted glass funnel filled with various solutions, by Lauer; metal plates covered by chamois skin soaked in normal saline solution, by A. D. Waller (5), and Stevanovic; metal electrodes attached to body, by kaolin paste, by Landis, Richter (1), and Syz (1); nickel electrodes, by V. J. Müller and Claparède; and "unpolarizable" gelatine electrodes, by Ebbecke (1). H. M. Wells (2) is one of the few investigators who has noted the effect of keeping the temperature of the saline solution of the electrodes constant by means of a thermostat. Gildemeister (13) has shown that the length of the latent period is directly dependent on the temperature of the electrodes. Knauer (1), after trying many combinations, decided that either zinc or carbon in concentrated ammonium chloride solution make the best electrodes.

The size of the electrodes has also been subject to experimental variation. This is usually a matter of convenience, although it is true that the greater the surface the less the effective electromotive force of polarization occurring at the electrodes. Wechsler (3) points out that there are three conditions to be considered in the choice of electrodes: (1) the part of the skin to which they are to be applied; (2) the security of the contact that can be assured; (3) the degree of polarization of the electrode itself. Because of this latter problem it is, of course, advisable to use impolarizable electrodes, but this is more difficult than it would appear. For example, Sidis and Nelson, in 1910, report the use of impolarizable platinum subcutaneous electrodes, while Dunlap (1) insists that not only do platinum electrodes show variations in deflection with slight physical alterations, but they also act definitely on organic substances. Landis has shown that most of the "unpolarizable" electrodes which he tested were polarizable. Strohl and Portes (1925), working on a number of electrodes called unpolarizable, have shown that when they are trav-

ersed by currents of feeble intensity they present counter electromotive forces which approach the strength of the current applied. Thus it would seem that electrodes at best are merely relatively impolarizable, and comparative experiments to be valid should be conducted with the use of similar electrodes.

D. Strength of applied current.—According to Wechsler (3), the absolute size of the deflection varies directly with the amount of current passing through the circuit. If this is the case, it is necessary that the ectosomatic current remain constant throughout any single experiment or throughout a series of experiments if the results are to be quantitatively compared. The voltage used by various experimenters depends to a large extent on the sensitivity of the galvanometer and the resistance in the circuit which they have employed. The great majority of those experimenters who specify the voltage used in their investigations use from two to three and one-half volts, although some have used as low a voltage as a few millivolts (Sidis and Kalmus), and some as high as twenty volts. Vigouroux (4) used fourteen volts (ten Leclanché cells), Binswanger and Kläsi, used fifteen volts, Godefroy (2) used from ten to twenty volts, and Aveling, who used the method of Godefroy (1), used twenty volts. Kaufhold points out that the resistance of the human body to galvanic currents is lower when using moderate potentials than when small potentials are used.

Sung-Sheng and Lehmann agree with Wechsler that the galvanometric throw increases with the electrical tension, but also found that neither absolute nor relative resistance fluctuations vary considerably from each other even with the use of different tensions. Gildemeister (6) and Philippson (1) point out the effects of variations on the frequency of the current and the difference in resistance when alternating or direct current is used.

III. The Physical Nature of the Psychogalvanic Reflex.

A. Physical causes.—A great deal of attention has been given to the problem of determining the exact physical causes and nature of the psychogalvanic phenomenon.

Tarchanoff, in 1890, proposed that this electrical phenomenon was mainly due to an electromotive force arising within the body. He found that during mental activity of the subject there are unequal changes of the static potential of the surface of the hands, and that if the hands are then removed from the electrodes, the difference of

potential is instantly equalized. From this he concluded that the changes in the potential of the body play a predominant rôle in the reflex phenomenon.

Sidis (1), and Sidis and Nelson, using the same methodology, hold that the phenomenon is caused by an electromotive force which is muscular in origin. Piéron (4) also suggests that the organic electromotive force may be of muscular origin. Prideaux (1) calls attention to the fact that Sidis (1) neglected the latent periods and hence may have been measuring at times something besides the psychogalvanic reflex. Furthermore, Prideaux (1) and Waller (10) state that the phenomenon may be produced without muscular movement of any sort. Philippson and Menzerath (2) believe that sensory or mental stimulation produce variations of potential in the human body of a diverse origin. These are: (1) A phenomenon exclusively cutaneous, distributed symmetrically over the surface of the body and manifested in asymmetric deviation toward negativity in the regions most rich in sweat glands. This is the phenomenon of Tarchanoff. (2) A muscular-cutaneous phenomenon affecting, in a preponderant manner, the right hand of the subject, rendering it positive in relation of the left hand. This phenomenon may be attributed to a distension of the skin following the involuntary contraction of the right hand in mental work. (3) A phenomenon exclusively muscular and due to the exaggerations of the action currents of the muscles.

Sommer (2, 3), in a study of the various physical phenomena which might cause the electrical phenomenon, concludes that it may be due to an electromotive influence of the body through mere finger movements under the hypothesis of static electricity on the surface of the body. Sommer (2) does not entirely deny that sweat secretion plays an important part in the reaction, but insists that components of an end-reaction may not be cited as causes of the reaction. Radecki (2) found that changes in the potential of the hands played a predominant rôle in the reflex. In 1918, Bénard and Schulmann demonstrated that stimulation of the tympanic nerve, producing marked salivary secretion and giving a marked diminution of salivary electrical potential, evokes a change which has a latent period and form of the psychogalvanic curve. Einthoven and Roos declare that the change of potential is but one of two causes which provoke the psychogalvanic reflex, the other being a change of resistance and polarization. Finally, Darrow, in 1927, in a summary of his work on the psychogalvanic phenomenon, calls attention to the fact that the galvanic skin reflex, when no external current is employed and

when the leads are taken by means of moist but non-liquid electrodes, is a function of relatively independent electromotive force and resistance changes.

A second factor which has been advanced in explanation of the psychogalvanic reflex is a change of skin or bodily resistance. This view was held by many investigators until Gildemeister (2) demonstrated experimentally that polarization was a major variable in the phenomenon. Both Vigouroux (1, 2) and Féré (2) called specific attention to the variations of electrical resistance offered by the human body, and stated that this was the predominant cause of the phenomenon. Wells and Forbes believe the phenomenon is caused by both a change in potential and a change in the resistance of the body. Peterson (2), in 1908, states definitely that the fluctuations of the galvanometer are due to varying resistance in the human skin, although it is possible that some extra-electromotive force is added. Starch claims that under normal passive conditions the bodily resistance is practically constant, but that during certain varieties of stimulation the resistance is decreased and the galvanometrical phenomenon results. Piéron (2) considers the phenomenon as a resistance change and states that the bodily resistance is essentially cutaneous. In a later article, however, Piéron (3) decides that there are at least two phenomena, electromotive force and resistance changes, and that perhaps the resistance is due to polarization. Peterson and Scripture, after denying the rôle of circulatory changes, say that the chief resistance of the body lies in the skin, and the effect must be attributed to variation of the skin. In summary, then, all investigators using an external current and working before Gildemeister (1, 2), with the exception of two or three who will be cited below, attribute the reflex mainly to changes in bodily resistance. The main objection that has been raised to the body resistance theory is the difficulty of measuring or ever determining accurately the true body resistance. Salomonson (2) attempted to measure the resistance of the body during the phenomenon by passing a constant current through the body and by introducing and short-circuiting a known resistance several times a minute. This method has been criticized by James and Thouless. In 1918, Strohl (1) attempted the same thing by adding to the circuit in series or parallel a very high supplementary resistance of known value of which the human body was merely a minute factor.

Strohl and Iodka (1, 2) have described a method making use of a radio three-element tube to measure the counter electromotive force of polarization. Using an applied voltage of twenty volts, they were

able to get varying electromotive force when the duration of current flow was raised from 0.00005 to 0.01 seconds, thus indicating that the counter electromotive force is in part dependent on the duration of the current flow. Weiss measured the internal polarization of the body by taking off the counter electromotive force with a condensor, and measuring it with a ballistic galvanometer. This potential, according to Weiss amounts to, from 0.2 volts to 0.25 volts. Galler, in a very nice piece of work, measured the resistance of the body, using both direct and alternating current, by measuring the amount of polarization during the flow of the current. David, in 1922, also presented a method of indirectly measurnig body resistance by factoring out the polarization effect.

James and Thouless, in 1927, showed that to credit the psychogalvanic reflex phenomenon to body resistance is a dubious procedure because of the impossibility of measuring the effect of polarization accurately. The only method available which is at all satisfactory is to use a slow moving galvanometer and a mechanically driven commutator. This method is difficult because if the rate of alteration of the current becomes high enough to exclude polarization effects, the electricity fails to penetrate the body, passing over the surface of the skin between the electrodes, thus obliterating the psychogalvanic reflex.

Polarization as a factor in the psychogalvanic reflex was not mentioned until 1909, when H. Müller (according to Dunlap (**2**)), stated that the phenomenon was probably due to polarization. Aebly, in 1910, and Galler, in 1912, pointed out that changes in polarization of the body as a source of exsomatic current must be taken into account in the psychogalvanic reflex because the skin possesses the property of polarizing itself strongly against the flow of the current. Gildemeister (**2, 3, 5**) believes the cause of the phenomenon is not due to the lessening of bodily resistance, but to a lessening of polarization which is localized at the level of the cutaneous membranes. This same author (**9**), in 1922, explains his theory more fully by saying that the skin is a polarizable structure in which the double charge is not static, but dynamic, and in this connection plays a great rôle not only for the tangent effects (*Elektrokinse*), but also for the transversal current. Again, in 1923, Gildemeister (**14**) restates his polarization theory, adding that the Veraguth phenomenon (psychogalvanic reflex) occurs simultaneously with the action current of the sweat glands and therefore cannot be regarded as due to the provision of a better conducting medium by the secretion which follows the

action current. Schwartz (1), Salomonson (1, 2), and Wiersma all agree with the above investigators that polarization plays the chief rôle in the reflex. Prideaux (2) states that the psychogalvanic reflex is definitely a polarization effect. Ebbecke (3) believes the apparent diminution of resistance is in part due to the removal of the opposing electromotive force caused by polarization of the cell membranes. Roos (3) notes that the current in individuals is produced by an increased electromotive force in the body, but that in others it is due to a diminution of the resistance and polarization of the skin. Roos (2) measured the influence of electrical resistance and polarization on the psychogalvanic reflex and concluded that polarization was the most important physical cause of the phenomenon. Strohl and Iodka (3, 4) and Heüman have also reported the effects of polarization on the psychogalvanic reflex.

Sommer (1) held still another view as to the cause of the psychogalvanic reflex. He conceived of the phenomenon as caused by mechanical variations of contact between the subject and the electrodes due to either voluntary or involuntary muscular movement. Gildemeister and Hoffman have also suggested that pressure on the electrodes may affect the reflex. Radecki (2) criticizes this view by saying (1) that if the phenomenon is of a muscular origin the relatively long latent period cannot be explained, for one knows that muscular reflexes are produced in less than one second; (2) the curve of rest is a line of descent and therefore is an electrical phenomenon not provoked by movement; (3) the time of the deviation is too long for a muscular reflex; and (4) a series of stimuli produce changes in various levels of the curve, proving them to be prolonged changes in the organism which would be impossible to ascribe to muscular pressure.

DuBois-Reymond, in 1853, first called attention to the fact that contraction of muscles would cause a galvanometer deflection. This work probably suggested the research of Tarchanoff. Peterson (1) reports that pressure on dry electrodes will increase the deflection, but that this could be obviated by the use of warm water contacts. According to Binswanger, changes of contact at the electrodes have no real effect upon the psychogalvanic reflex, but involuntary pressure on the electrodes effects a throw of the galvanometer. Sidis (1) and Sidis and Nelson say that the reflex is entirely a muscular phenomenon brought about chiefly by muscles within the circuit. On the other hand, Veraguth (1) and Ricksher and Jung believe that involuntary changes of the area of contact at the electrodes cannot be

the only cause of galvanometric fluctuations. Piéron (1), after calling attention to the obscurity of the causes of this phenomenon, insists that it is not due to poor contact with the electrodes nor to muscular contractions. Similarly, Waller (10) found that slight muscular movement does not affect the psychogalvanic reflex, a fact which Moravcsik has confirmed. Prideaux (1) criticizes the work of Sidis and shows that the reflex can be elicited without muscular movement.

It has been suggested by Radecki (2) that some sort of chemical reaction between the electrodes and the body might cause the galvanometric fluctuations observed in the psychogalvanic phenomenon. There is a lack of data on this point, although Dunlap (1), in a criticism of Sidis' (1) work, calls attention to the fact that platinum in contact with organic fluids can produce an electromotive force. Radecki (2) was unable to list chemical reactions between the skin and electrodes as a cause of the phenomenon because (1) when litmus is placed between the two, there is neither an acid nor base reaction found, and because (2) the phenomenon occurs independently of the nature of the electrodes, *i.e.*, they may be solid, liquid, copper, zinc, etc. Further investigation of this phase might lead to interesting results.

B. Physical factors influencing the psychogalvanic reflex.—Wechsler (3) and others claim that the absolute magnitude of the galvanometric deflection is in part dependent upon the intensity of the current passing through the circuit. Wechsler (3) found a direct relationship between both the intensity and the duration of the current and the magnitude of the deflection. Hence, he states that it is essential that the intensity of the ectosomatic current be kept constant throughout the experiment, if comparison of results is to be made.

Gildemeister and Kaufold, in 1920, conducted several interesting experiments as to the effect of direct and alternating currents on both living and dead bodies. Their results indicate: (1) that the resistance to direct current appears smaller as the voltage of the measuring current increases, and with a return to low voltage the resistance depression remains; (2) resistance to direct current decreases with time, when the measuring voltage is maintained constant; (3) resistance to alternating current is smaller than to direct current and does not produce such large fluctuations; and (4) the above results were obtained both from living and recently dead human bodies.

Another question of importance in this connection is the effect of placement and kind of electrodes. Tarchanoff and the majority of

the experimenters agree that larger deflections are secured when at least one electrode is placed in a region of dense sweat glands. Leva, in 1913, showed a close relationship between the number of sweat glands in a given area and the size of the galvanic deflection. Wechsler (3) goes so far as to say that the electrodes must be placed in a region rich with sweat glands in order to produce the psychogalvanic phenomenon at all. Georgi confirms Wechsler, as he found that the reflex could not be elicited from the palms and soles of a subject who lacked sweat glands. Aveling and McDowall (1), on the other hand, have been able to obtain deflections even when the skin was removed. Using hypodermic electrodes, both Sidis (1) and Sidis and Kalmus were able to obtain a deflection, although it was only about 1 per cent as great as when the electrodes were applied to the skin. Sommer (1) found greater deflections from the finger tips than he did from the palms, which are relatively more abundant in sweat glands. O. Albrecht found that increased electromotive force is dependent upon secretions of the skin glands. A discussion of varieties of electrodes has already been given above (Methodology). It is sufficient to say that a controlled study of the placement of electrodes and of the variation caused by the employment of different kinds of electrodes would aid future research materially.

That muscular movement influences skin electrical phenomena was first noted by duBois-Reymond in 1853 (Waller (3)). Investigators who have called specific attention to the effect of muscular movement on the phenomenon include Sommer (1, 3), Sidis (1), Sidis and Nelson, and Wechsler (3). Although it is doubtful as to the extent that muscular movement affects the reaction, it seems to be well established that it does influence the reflex unless precautions are taken to control this factor.

Closely allied to muscular movement is the influence of pressure on the reaction. Sommer (3) points out that a typical curve may be obtained by variation of the pressure on the electrodes even when no human body is in the circuit. Peterson (1), Binswanger, and Moravcsik have also noted that pressure applied to the electrodes may increase the amplitude of the deflection. In careful experimentation then, it is essential that either liquid electrodes be used or that precaution be taken to prevent changes in pressure when solid electrodes are made use of.

Very little experimental work has been done on the effect of temperature changes of the skin on the galvanometric fluctuations. Sidis

and Kalmus in 1909 reported that heat and cold give but slight variations and that the deflections are the same for both heat and cold. These authors indicate also that the resistance of a given body is dependent to some extent on its temperature. Zimmern and Logre (1) were unable to obtain the reflex in subjects suffering from chills or fever, although they insist that the phenomenon is not due to temperature. Bujas in 1922 was the first investigator to lay particular emphasis on temperature as the cause of the galvanic reflex. This author believes that the body behaves like an electrolyte and that a current arises if there is a variation of temperature at any point between the metal electrodes. Bujas based his whole statement on more or less theoretical grounds. Gildemeister (13) in the following year made an experimental study of the relation of the psychogalvanic reflex to the temperature of the skin. He obtained some very interesting results, among which the following are of special importance; (1) the positive variation of a constant current passed through the skin on stimulation of the skin surface (Veraguth's phenomenon), is accentuated by raising the temperature of the electrodes; (2) local warming increases both the latent time and the duration of the reflex; (3) the latent period of the Veraguth reflex varies greatly with the temperature of the skin but is remarkably constant at a fixed temperature. Gildemeister's work is of high caliber and has added materially to our knowledge of physical factors which may influence the psychogalvanic reaction. Lewis and Harmer have also noted the effect of temperature on the reflex. H. M. Wells (2), in 1927, seems to have been the first investigator to take into account the possible influence of changes in temperature of the electrodes on the reaction, by keeping the temperature of the saline solution constant throughout the experiment by means of a thermostat. Landis has shown that there is no relationship between temperature changes of the skin-electrode juncture and the resistance of the body.

That repeated stimulation of sense organs causes a decrease in the amplitude of the galvanometric deflection was pointed out by Tarchanoff in 1890. Since that time this effect has been noted by most experimenters. Peterson and Jung, in 1907, reported a gradual diminution of the reflex to almost complete extinction in long experiments. Farmer and Chambers (1925) report that repetition caused the reflex to disappear entirely, but that it reappeared again with the same stimuli after the subject had spent a week-end in the country.

From the above review of the various incidental factors which may influence the psychogalvanic reaction it is clear that extremely careful technique must be employed if results which are secured may be considered reliable.

C. A comparison of the methods of Tarchanoff and Féré.—It has long been a matter of conjecture whether the phenomenon which is elicited when a galvanometer is connected in circuit with the body and a battery, and the phenomenon discovered by Tarchanoff, are two aspects of the same thing, are two distinct phenomena, or are causally related phenomena. Jeffress (1928) calls attention to an experiment by Farmer and Chambers in which they measured the size of the deflection obtained from the two hands simultaneously with two instruments, one connected to the hand directly and one through a Wheatstone bridge. They found a high degree of relationship between the two but do not mention the actual degree of relationship. Farmer and Chambers conclude that obviously the Féré and the Tarchanoff phenomena are not due to the same immediate cause. Wechsler (3) has proposed that the Tarchanoff phenomenon is the same as Féré's. Attributing the Tarchanoff phenomenon to a change in polarization, he says it is merely a special case of the phenomenon of Féré. He continues his argument by insisting that Radecki (2), and Sidis and Nelson, commit a very fundamental error by assuming that the mere fact that the galvanic response was obtained without exsomatic current is sufficient proof that the phenomenon is due to the production of a new electromotive force. "As a matter of fact," Wechsler states, "when any two points of the skin are connected, there is immediately set up . . . a current due to the difference of potential between the two points connected. The current then traverses the body, and so far as the body is concerned, it makes no difference whether the current is exsomatic or endosomatic. When no external current is used there is gradually a falling off of the initial current, indicating clearly a polarization effect similar to the one observed when an exsomatic current is used." Jeffress justly criticized this theory of Wechsler by saying that "the Tarchanoff phenomenon occurs when there is no polarization, because no current is flowing as body potential is neutralized by an external potential obtained from a potentiometer." Also Jeffress noted that the phenomenon continues in the same direction when the current is flowing (and hence the counter electromotive force of polarization), in the opposite direction. Under this latter condition the deflection should be reversed if Wechsler's theory were correct. In continuing his work, Jeffress

found: (1) a coefficient of correlation of $+.95 \pm .014$ between the magnitude of the deflections obtained with and without an ectosomatic source of potential; and (2) that both phenomena exhibit the same latent period. The hypothesis that Jeffress suggests which accounts for the relationship between the two phenomena, as well as for the discrepant results obtained by other investigators will be considered under physiological causes of the reflex.

Einthoven and Roos believe that the causes of the two phenomena (that of Féré and that of Tarchanoff) are situated in different organs as in some persons where the resistance-polarization factor is lacking, the electromotive force effect is considerable. Philippson and Menzerath (1) also point out that the two phenomena are different, one (the Tarchanoff phenomenon), being due to the distention of the skin by a contraction of the muscles and the other (the Féré phenomenon), being due to secretory phenomena of the skin.

It seems evident that although the two phenomena under observation are not different aspects of one and the same phenomenon, they are very closely allied to one another in their causal relationship.

D. The psychogalvanic curve.—At the beginning of the experiment, when the subject is at rest and the electrical circuit is closed, it is noted that there is a relatively large initial deflection of the galvanometer. Farmer and Chambers quote Guilleminot as saying that this apparent diminution of resistance is due to "ionization" of the skin. This diminution continues so long as the ionization is incomplete, so that all measures of the psychogalvanic reflex which do not take this factor into account are inaccurate. (The term *polarization* is more accurate than *ionization.*) Veraguth (5) has named initial change the curve of rest because it occurs while the subject is quiet and undisturbed. Veraguth further states that the curve is always the same, but Wechsler (2, 3), was able to produce three varieties of this rest curve depending on the placement of the electrodes. Philippson and Menzerath (2) have also reported this curve of rest and state that it is a polarization effect. Veraguth (2) found that it took about 15 minutes before the psychogalvanic curve became stable enough to begin accurate experimentation. Wechsler (2) allowed at least 10 minutes for the curve to reach stability.

A second typical feature of the psychogalvanic reflex is a certain latent period of appearance. Radecki (2) reported latent periods as short as one second while Abramowski has observed latent periods as long as 15 seconds. However, more recent investigators have found the latent time in most cases to be from two to three seconds.

Peterson (1) found that in abnormal subjects the latent period may be as long as 20 seconds. Hermann and Lucksinger report that it is shorter in warm-blooded than in cold-blooded animals. Abbot and Wells report that the latent period is normal in stuporous conditions. Prideaux (2) is of the opinion that the length of the psychogalvanic latent period is good evidence against the validity of the James-Lange theory of emotions. Golla holds the opposite opinion.

A third characteristic of the psychogalvanic response is a small negative deflection which usually precedes the main deflection. This was first noticed by Sticker who believed it was due to the vasodilation of the blood vessels. Wechsler (3) believes this is due to imperceptible muscular contractions that are caused by slight movements of the body regions which are in contact with the electrodes. Thouless (2) states that he was never able to get a negative deflection except with imperfect electrode contact. A phenomenon closely related to this initial negative deflection, is the small negative deflection which sometimes follows the normal positive deflection. No wholly satisfactory explanation has yet been given these two phenomena and a further research on these characteristics is needed. Hermann states that a pure negative throw is never found.

IV. The Anatomy of the Psychogalvanic Reflex

The neuroanatomical path of the psychogalvanic reflex has been a matter of some dispute and uncertainty because most of the work has either been done on frogs or by means of the action of drugs which affect specific types of nerve control. Veraguth (5) states that the endosomatic current is from two sources, the action current of nerves, especially the spinal, and from the afferent nerves along with motor nerves of the thenar and lambsical regions. Veraguth (4) also found in a case of total spinal transection at the lower dorsal level, the deflection is normal when the subject is aware of the stimulus which is to be used. When the subject was blindfolded the results were confused. Peterson (2), although giving no experiments to verify his hypothesis, is of the opinion that the psychogalvanic reflex is due to resistance variations probably mediated over the sympathetic nervous system. V. J. Müller (1913) found that the reflex phenomenon is abolished in animals when the nerve tracts which innervate palmar and plantar surfaces are broken by perineural injection of an anaesthetic. He failed to obtain valid results when working with humans. Gildemeister (2, 10) rejects the view of

earlier experimenters that the galvanic response was conditioned by the functioning of the higher centers. He believes that the phenomenon is of a purely reflex nature which is in no way dependent on the higher processes and suggests that the phenomenon be renamed the "neurogalvanic" reflex. The evidence as to whether or not Gildemeister's view is correct is contradictory.

Speranskaia (1) shows that the skin glands of the frog's hind legs are innervated by the sympathetic nervous system. This suggests that the sympathetic system is innervated during psychogalvanic activity. The researches of Lewis and Marvin uphold this point of view.

Veraguth (5) and Wechsler (3) were unable to obtain the reflex in the case of a cat under anæsthesia, a finding which Fauville as well as Dennig confirm. On the other hand, Schilf and Schuberth destroyed the entire central nervous system of the frog above the lower fourth of the medulla, and were still able to obtain the reflex. They therefore conclude that the reflex center is in the medulla. Fauville (1921) found that the reflex was abolished when electrodes were placed on the hind legs of the frog and the sciatic nerves severed. He made no attempt to discover whether the fibers mediating the reflex were of spinal or of sympathetic origin. Schilf and Schuberth subsequently have separated a frog in halves in such a way that the sole connection between the front and rear half was made by sympathetic fibers. Under such a condition, pain stimuli applied to the anterior half produced a galvanic reflex, thus proving that the galvanic response is mediated by the sympathetic nervous system. Zimmern and Logre (3), Dennig, and Richter (3) confirm the results of Schilf and Schuberth. Longridge (1916), using the galvanometer on wounded soldiers, says that his results give definite proof of the main contention of the theory of Baines (1914) who says concerning the psychogalvanic reflex that "the brain is the seat of generation of an electromotive force which is carried to the tissues by means of the nerves." The experimental evidence, however, is extremely questionable. By far the best research to date on this problem is that of Foà and Peserico. These experimenters first conducted their experiments by direct nerve or spinal cord sectioning on the cat and then later checked their results against the drug effects. Their most important findings follow. (1) Direct stimulation of the sciatic nerve or of the brachial plexus produces the psychogalvanic reflex. (2) Sectioning the sciatic nerves abolishes the psychogalvanic reflex. (3) Sectioning of the spinal cord above the 12th dorsal segment

abolishes the reflex, while sectioning below the 3d lumbar segment does not affect the reflex. (4) The psychogalvanic reflex travels centrifugally over the autonomic fibers of the sciatic nerve. (5) Sectioning of the lower bulb of the medulla abolishes the psychogalvanic reflex with any stimulation arriving over any sensory nerve. (6) The center of the psychogalvanic reflex is localized in the corpora quadrigemina and the apex of the calamus scrittorius. (7) Peripheral stimulation starts impulses traversing any sensory nerve which in turn communicates with the bulbar region. Here it is elaborated, descends the spinal cord to between the 12th dorsal and 3d lumbar where it leaves over the sympathetic fibers following the sciatic nerve to the sweat glands which in turn cause the appearance of the psychogalvanic reflex.

V. The Physiological Nature of the Psychogalvanic Reflex.

A. The Effect of the General Physical Condition of the Body.— That both physical and psychic fatigue diminish the reflex was noted as early as Tarchanoff. That fatigue reduces the electrical conductivity of both animal and plant tissue has been shown by Bose. E. K. Müller (2) was the first investigator to show that not only was the deflection greater when the subject was rested but also that the size of the deflection varied with the hour of the day. Müller failed to state at what time of day the resistance was greatest.

Waller (10, 11) found diurnal variations in bodily conductivity, noting particularly that body resistance is much higher in the morning just after awaking than it is in the evening before going to sleep. Golla made similar observations of the diurnal variation in resistance. Wechsler (3) repeated the observations of Waller and getting the same results he concluded that the high resistance in the early evening and at night leaves one to suppose that there must be some correlation between the degree of fatigue of an individual and his body resistance. Wechsler makes no attempt to account for the high resistance in the morning after a good night's sleep. Richter (2) states that the bodily resistance increases in proportion to the depth or intensity of sleep and that no matter how suddenly the subject is awakened, the resistance instantly drops to the pre-sleeping (waking) level. Landis attempted to repeat the experiment of Richter using the latter's technique as far as possible. His results show that after an initial period of adaptation there is no change in the "true" ohmic resistance of the body during the eight hours of sleep, and that there is no correspondence between the depth of sleep, postural

activity, skin temperature, and electrical changes determined by the method of Féré.

Most investigators are in agreement that deep respiratory movement provokes a psychogalvanic reflex. However, Binswanger insists that deep sighs and breaths act as a stimulus for the reflex only when considered by the subject as of emotional significance, but gives no clue as to the manner of discovering whether or not it has such a significance. To the reviewers it appears that Binswanger attaches a rather far fetched significance to this simple physiological function. Peterson and Jung compared pneumographic curves with psychogalvanic curves and found no parallelism between the two reactions. They, however, did find that sudden respiratory movements such as coughing produce a galvanic reflex. Radecki (2) gives evidence against the above viewpoint by showing, that if the subject voluntarily forces expiration there is a galvanometric deflection, and that voluntary holding of the breath gives a periodic, successive lessening of the curve. The possibility that respiratory movements call forth the electrical response directly without the mediation of the psychological processes as suggested by Peterson and Jung led Wechsler (3) to investigate this problem. Using an anæsthetized cat, he sectioned the left pneumogastric, stimulated the central stump, and then sectioned the second pneumogastric. His results show that variations of respiration produced either by the sectioning or excitation of the nerves were not accompanied by electrical variations, thus giving evidence in a negative way, in favor of the hypothesis of Peterson and Jung.

It is interesting to note that although mental activity seems to increase the resistance of the body and cause a diminution of the galvanic reflex, physical exercise has the contrary effect. Radecki (2) found that muscular exercise causes a marked diminution of the resistance of the body which he ascribes to modifications of circulation. Strauss states that the fall in resistance is proportional to the severity of the exercise. Wechsler (3) admits the effect of muscular exercise but suggests moistening of the skin or opening of the pores as the probable cause.

B. Physiological processes causing changes in conductivity.— That the sweat glands have some influence on the magnitude of the galvanic reflex was first recognized by Vigouroux (4) in 1888. Leva was the first to investigate the exact relationship of the sweat glands with the psychogalvanic reflex, finding a very close relationship. Tarchanoff (1890) stated that electrical variations observed in the

skin as a concomitant of nervous activity may be considered as currents of secretion during the active state of sweat glands. Veraguth (5) felt that he confirmed Tarchanoff's statements by drying the fingers of the subject with formalin or a belladonna plaster applied to the hands for several hours with a resultant diminution of the reflex. Peterson (2) likewise found that drying the skin with formalin increased the resistance so greatly as to completely suppress galvanometric deflections. Wells and Forbes state that atropine probably reduces the difference of potential between the two hands; at any rate, it clearly reduced the psychogalvanic reflex. Bayliss (1) found that activity of the sweat glands was one of the main causes of the phenomenon. Bayliss and Bradford report that Hermann found that atropine frequently abolished the electromotive force. Finally, Leva found that atropine definitely abolished the reflex, thus apparently proving that the phenomenon is dependent on sweat gland secretion. The work of Leva with atropine was not questioned until 1918 when Waller (10) found that atropine had no effect on the skin response. Further work by Waller (14) and by Marktbreiter (in collaboration with Waller) seems to show that although pilocarpine gave an increased conductivity, atropine pushed to limit dosage neither affected conductivity or the psychogalvanic reflex. Marktbreiter confirmed Waller by showing that although atropine raised the resistance very markedly, it abolished the reflex in only one out of six cases even with marked dosages. Fauville (1923) found that both atropine and pilocarpine abolish the reflex although they have an opposite effect on the sweat glands. Schilf and Manden found that adrenalin, injected into the sole of the foot, has no influence on sweat secretion either before or after the sectioning of the sciatic nerve or spinal roots. Foà and Peserico point out that the effect of pilocarpine depends on the dosage. Richter (1) shows that skin resistance is increased by adrenalin and atropine and decreased by pilocarpine. From the above results of the action of drugs it seems evident that one of the main causes of conflicting results is the difference in susceptibility of the individual subjects.

Burn (1) studied the relation of the nerve-supply and blood flow to sweating produced by pilocarpine and found that the changes in secretion following either sympathetic or complete denervation are closely parallel to the changes in the vasomotor reaction of the limb to histamine. Langley states that adrenalin causes secretion only in virtue of the fluid in which it is dissolved and that its secretory action is confined to the area in which the fluid is injected. Langley and

Uyeno point out that all aqueous solutions which are not injurious tend to stimulate the sweat glands. Speranskaia (2) also found that adrenalin usually provokes a " local " secretory reaction which is independent of the integrity of the nervous system, but found cases where it had an inhibitory effect. Burn (2) states that pilocarpine has a dilator action on the blood vessels which is similar to histamine. He also points out that the loss of the sweat response is due to degeneration of the motor fibers of the muscles and not to a degeneration of sympathetic or sensory nerve fibers. Chanoz found that various acids have a varying effect on the electromotive phenomena of the skin. E. W. Reid has shown that even the non-secretory epithelial membranes have electromotive properties. As has been already noted, Tarchanoff suggests that the sweat glands secrete sweat after nervous activity in order to cool the body after the heat set up by the nervous strain. Stickler, finding that the reflex could be obtained from parts of the body under anæsthetics, rejects Tarchanoff's secretion theory. Peterson and Jung believe the reflex is due to a diminution of resistance caused by a hypersecretion of sweat. Zimmern and Logre (1) have adopted a view similar to that of Peterson and Jung except that they attribute the diminution to a freer flow of sweat into the *conduit excreteur* instead of a hypersecretion of sweat. That Peterson and Jung's hypothesis was not true is shown by various investigators. Both Waller (14) and Golla failed to find an extraordinary large reflex in the case of a subject suffering from hyperidrosis (excessive sweating). Georgi, reports that in one of his subjects suffering from hyperidrosis, the resistance of the skin was greatly lowered. Aveling and McDowall (1) obtained deflections even when the skin of a cat was removed and the electrodes placed on the muscles, indicating that sweat is not the sole cause of the reflex. Sidis and Kalmus covered the hand with shellac and paraffin and found that this did not affect the response in any way. Peterson and Scripture criticize this experiment of Sidis and Kalmus because if the hand were properly covered (insulated) the resistance would be infinite. Darrow found an almost perfect positive correlation between changes in the galvanic skin phenomenon and the moisture changes from the sweat glands while Gildemeister (8) has shown that the sweat glands play an important rôle in the production of the psychogalvanic reflex. Bayliss (2), Darrow, and Ebbecke (2) all agree with Waller that electrical resistance is due to changes in the permeability of the cell membranes. Schwartz (1) similarly believes that there is an increase of permeability of the cell membranes, especially sweat cells and per-

haps epidermis cells also. Thouless (1) shows that the phenomenon is not primarily due to either increasing polarization or penetration of the skin by ions. Gildemeister (2, 3) questions certain of the theories thus far mentioned because they assume that the observed diminution of resistance is real, that is, a true ohmic variation and not merely an apparent one. This, Gildemeister found to be an error, as the apparent resistance was caused by the diminution of the counter electromotive force of polarization set up by the applied external current. This diminution in the counter force of polarization, Gildemeister believes is the result of activity of the sweat glands. Wechsler (3) has accepted the view of Gildemeister and attempted to extend it to account for the Tarchanoff as well as the Féré phenomenon. Jeffress attacks Wechsler's extension because it is quite evident that the Tarchanoff phenomenon occurs when there is no polarization because no current is flowing (he produces "this condition by neutralizing the body potential by an external potential obtained from the potentiometer"). Jeffress presents a very interesting hypothesis based on the semipermeable membrane theory which is deserving of further investigation. He presents the following theory which accounts for the close relationship between the two phenomena as exhibited by Tarchanoff and Féré. "The reactions obtained when no source of potential is used (Tarchanoff's phenomenon) are action currents of the sweat glands. The activity is shown electrically by a current directed inward from the surface of the skin. It is accompanied by a change in permeability of the membrane of the glands which in turn results in a change in electrical polarizability. This latter exhibits itself electrically as a variation in counter electromotive force with the consequent variation in apparent resistance which is known as Féré's phenomenon." Philippson and Menzerath (1, 2), on the other hand, believe these are two independent orders of psychogalvanic reactions. The Tarchanoff method, they ascribe as due to the distention of the skin by a contraction, of varying degree, of the muscles, while the Féré phenomenon is due, they believe, to the dependence of certain electrical reactions on the secretory phenomena of the skin.

That the sweat glands appear to play some part in the normal psychogalvanic reflex cannot be denied, but in view of so many conflicting results, no definite conclusion as to the physiological rôle which they play, can at the present time be attempted. Waller (14) suggests that the relation between the psychogalvanic reflex may be merely a parallel relationship and not a serial one, and thus he avoids

all of the previous contradictions as to the relationship which exists.

Vigouroux (1, 4) in 1879 was the first investigator to attribute the variations in the electrical behavior of the skin to the vasomotor system. He states that the diminution of resistance always depends on the dilation and easy flow in the cutaneous capillaries and perhaps also of the deeper blood vessels. Féré (2) found that the variations in electrical resistance of the body are coincident with the plethysmograph curves and concluded that the diminution of electrical resistance goes with the increased irrigation of the tissues. Hallion and Compte likewise found parallelism between electrical resistance and plethysmographic curves from the fingers. Sticker, in 1897, finding that Tarchanoff's secretion theory was inadequate to explain the galvanic phenomenon, suggests on the basis of his own results that it is a complicated phenomenon in which the psychic excitement and the current of secretion influence both the local capillaries and the capillary system in general, and reciprocally, these factors constituting together the make-up of the phenomenon. Radecki (2) has enlarged upon the theories of the above investigators and concludes that the response is due to variation in the carbon dioxide concentration of the blood. His interpretation of the whole phenomenon is as follows: "A vasodilation, provoked by a psychic excitation and following circulatory modifications in speed and in blood pressure, causes an increase in the gaseous exchange of the body and carries along, because of this, an increase in the conductivity of the human body." Radecki hooks up his circulation theory with the known facts concerning the rôle of the sweat glands in the production of the phenomenon by explaining that the changes of potential of the human skin arise from the setting free of electricity which takes place during glandular activity. Thus he connects these changes with secretory and excretory processes. No other supporter of this theory appeared until 1924 when Uhlenbruck (1) took simultaneous records of the psychogalvanic reflex between the thumb and the little finger and of the volume changes of the index and ring fingers enclosed in a plethysmograph. He found that the psychogalvanic reflex is almost always associated with a volume change. Uhlenbruck (1), however, is careful to show that simultaneity does not necessarily demonstrate a causal connection. It should be also noted that Leva, although ascribing another cause for the reflex, found that changes in blood distribution are especially evident with psychical stimuli in hypnosis, and that Zimmern and Logre (1) found that electromotive changes run parallel to vasodilation or vasoconstriction changes, although they

ascribe the cause of the changes to sweat gland activity. Aveling and McDowall (2); Aveling, McDowall and Wells; and McDowall and Wells, have published results showing that in a chloratosed cat, a fall of electrical resistance of the skin is associated with the constriction of vessels and a rise with dilation. Wells points out, that in cold weather it is hard to elicit the psychogalvanic reflex because the skin vessels are already constricted; that pressure on the electrodes may prevent the psychogalvanic reflex, and that the greatest deflections are obtained from the palms and soles where superficial blood vessels are well protected by a greatly thickened stratum corneum (most investigators have found the opposite reaction from pressure on the electrodes); that large doses of drugs such as alcohol and atropine, which cause marked dilation and paralysis of the skin vessels, abolish the psychogalvanic reflex; that the psychogalvanic reflex is evoked only after great difficulty in patients suffering from arterial disease, *i.e.*, arteriosclerosis. These results, if confirmed, will give valuable evidence that the vasomotor system is in part, at least, responsible for the psychogalvanic reflex. Wells (2) in a continuation of the above experiments was able to substantiate all of the results previously obtained and concludes that although it is clear that changes in the blood vessels do modify the electrical resistance, we are not yet able to state just how they do it. New blood corpuscles have a relatively high resistance but it is evident that this alone would not account wholly for the observed changes.

There have been several arguments proposed against the vasomotor theory as put forward by the investigators cited above, the most important one being that first advanced by Veraguth (1). He found that the reflex could not be due to changes in the amount of blood in the hands for when the electrodes were placed on the hand exsanguinated by an Esmarch bandage, the reflex was in no way affected. Piéron also objects to Radecki's theory because when he exsanguinated the arm with an Esmarch bandage a reflex occurred which was in no respect different from the normal psychogalvanic reflex. Waller (10), making the limb pulseless and exsanguine by means of an India rubber band, was also able to get a normal psychogalvanic reflex. Einthoven and Roos were unable to obtain any galvanic reflex when the electrodes were applied to the temples, cheeks, or forehead of the subject although these regions respond to emotional stimuli by marked vasomotor reactions (blushing). Sidis and Kalmus found that heat and cold, which usually cause vasomotor changes, had but little effect on the psychogalvanic reflex.

Radecki (2) in a reply to these objections states although his theory has been ignored because of the fact that the reflex was not abolished by the cutting off of the blood supply to the part concerned, it should now be realized, largely as a result of the investigations by Krogh, that the peripheral vessels are independent of the blood pressure and thus such negative evidence carries no weight. Densham and Wells (2), believing that Veraguth's statement that exsanguinating the arm caused no change in the reflex was improbable because stoppage of the arterial blood supply tends to diminish all reflexes, conducted an experiment with an exsanguinated arm. They found, contrary to Veraguth, that a limb deprived of its arterial supply showed a much reduced psychogalvanic reflex. They explain the contradictory results as due to the fact that previous experimenters had used unreliable stimuli. Veraguth (1) used tactile, optical, and acoustic stimuli. These stimuli, Densham and Wells (2) showed to be unreliable in comparison with faradic stimuli applied to the neck.

Thus it would seem that in some manner, the vasomotor system enters into the galvanic phenomenon, but we must await further evidence before any definite conclusions can be drawn on this very controversial point.

A third cause which has been advanced to account for the psychogalvanic reflex is muscular movement. Sommer (1, 2, 3) first declared that the reflex was caused by involuntary nervous contractions which give rise to differences in pressure on the electrodes, thus showing an electromotive manifestation. Previous to Sommer, duBois-Reymond (1849) had called attention to changes in electromotive force generated by the contraction of a limb. Sommer, however, admits the various other theories as partial causes of the galvanic reflex but believes that muscular contraction must also be considered as a cause. Harnack suggests that the galvanometric deflection may be due to muscular currents or muscular friction and suggests further scientific study of the electrical magnetic properties of the body.

In 1910, Sidis (1, 2) and Sidis and Nelson attempted to show that psychogalvanic deflections under the influence of affective states are due to electromotive forces liberated by muscular activity brought about by sensory, emotional, and affective processes. They cite as evidence for this theory, the following results: (1) when a rabbit's legs were held motionless, no stimulus was able to produce the reflex, but as soon as one leg was freed, the phenomenon occurred normally; (2) there can be no psychogalvanic reflex obtained when the motor

nerves of the frog's legs are cut; (3) repeated stimulation decreases the reflex due to a gradual fatigue of the muscles; (4) the heart beat, like the contraction of any muscle, produces an electrical discharge. Philippson and Menzerath (2) believe that the phenomenon may be exclusively cutaneous, muscular cutaneous, or exclusively muscular and give facts to support this view. Goebel says that most likely, variations in the strength of the current are dependent upon partial momentary variations of the state of contraction and tonus of the muscles through which the current flows. Piéron (1, 2) states that the reflex is not due to muscular contractions but offers no experimental proof against this theory. Prideaux (1) criticizes Sidis (1, 2) because he neglected latent periods and because he failed to state the intensity of the current which he used. Waller (10, 16) found that slight muscular movement had no effect on the reflex and that a shifting of the electrodes caused a movement of the galvanometer in a direction contrary to that of the psychogalvanic reflex. Dunlap (1) also offers criticisms of the methodology used by Sidis in his experiments on the psychogalvanic reflex. That muscular activity plays some part in the reflex is quite possible, and well controlled experiments should be carried out in the future in order to either definitely confirm or disprove this theory.

Besides the sweat, vasomotor, and muscular theories, several other theories have been advanced. That respiration affects the galvanic phenomenon has been shown by many experimenters (*e.g.*, Waller (13), and Nunberg), but since respiration is so closely related to vasomotor activity a detachment of the two seems to be superficial. This also applies to the effect of temperature variations as reported by Hahn and Lueg (1, 2), Bujas, and Gildemeister and Ellinghaus (13) since changes in temperature are probably coincident with vasomotor reactions.

Thus far we have considered the various physiological reactions involved in the electrical phenomena of the skin and although most investigators have decided opinions as to which of the causes is predominant, conflicting evidence forces us to wait for further, better controlled and more scientific experimentation before accepting any definite physiological explanation. We do not, in view of all the evidence thus far submitted, go to the extreme of Prince and Peterson (2) who say that to explain the psychogalvanic reaction by a physiological reaction theory is possible but far fetched.

VI. A Psychological Study of the Psychogalvanic Reflex

That affective stimuli are capable of evoking the phenomenon was realized as early as Vigouroux (4) and Féré (1) who state that the electrical tension and the intensity of the discharge is augmented under the influence of the moral emotion. Binswanger in 1907 first stated that *only* emotional stimuli affect the psychogalvanic reflex. This view has since been held by several investigators including Piéron (3) who does not justify his theory with experimental facts. Kuhne, Zimmern and Logre (1) (who changed their viewpoint after further investigation of the literature; see Zimmern and Logre (3)), Litwer (2), Godefroy (2, 3), and Wechsler (3, 4), all advance the theory that only psychic stimuli which are affectively toned are capable of producing the reflex. Wechsler (3) is the only one who goes into detail to uphold his point of view. He insists that it is the affective tone which accompanies such sensations as the sound of a gun or the prick of a pin and not the sensation itself which produces the psychogalvanic reflex. He then proceeds to show how it is the affective tone which also conditions stimuli termed as mental effort and attention.

Peterson (1), Peterson and Jung, and Peterson and Scripture were the first investigators to claim a relationship between the magnitude of the galvanometric deflection and the intensity of the emotional stimulus. Using introspective report as the criterion for the intensity of the emotion produced in the subject, these investigators conclude that every stimulus accompanied by an emotion causes a rise in the electrical curve, and that, directly in proportion to the liveliness and actuality of the emotion aroused. These studies are of course open to the serious objection that a quantitative introspective report is at best, very unreliable. Waller (16) believed that the psychogalvanic reflex shows how much a given subject is moved by his thoughts and feelings. Prideaux (2) says that the psychogalvanic reflex is, in the same person at the same time and under the same conditions, an indicator of the intensity of crude emotions as subjectively experienced. W. W. Smith (2) modifies this view by saying that the psychogalvanic reflex appears to be *approximately* proportional to the intensity of affective tone. Syz (2) found a direct relationship between the *frequency* of the psychogalvanic reflex and the subject's description of the emotional make-up of stimulus words in a free association test. In a later article, Syz (3) points out great discrepancies between the deflections and introspective reports of

the emotional experience, and suggests that a social factor keeps some emotional responses from awareness and leads to belief in others which are non-existent. Such a viewpoint, involving "unconscious" emotions, seems to the reviewers untenable since the awareness of the emotion is considered an indispensable part of the emotional experience and therefore such an experience as Syz (3) calls an unconscious emotion is not an emotion at all.

Aveling takes exception to the theories thus far presented because he found no reliable correlation between the frequency of the galvanometric deflections and the subjects' introspective reports. Aveling's finding that affection is seldom reported when there are deflections of the galvanometer, might be explained by saying that the affective tone was so feeble that it was soon forgotten and thus escaped the attention of the subject when he was giving his introspective report at the close of the experiment. His finding that affectively toned experiences often give no deflections must be taken as an indication that the psychogalvanic reflex is not a reliable indicator of affection. Gopalaswami (1) found that with increasing practice in mirror drawing one obtains an increasing deflection of the galvanometer, a fact which he interprets as indicating that the psychogalvanic reflex is not an index merely of the intensity of emotion, but also an indicator of increased learning effort.

Radecki (2), Sidis (1), and Sidis and Nelson found that although every sensory stimulation of an affective or emotional value is accompanied by a galvanic deflection, it is not true that affective stimulation alone is capable of evoking the reflex. Gregor (1) was able to demonstrate the psychogalvanic reflex with intellectual work which was difficult for the subject although it was in no way affectively toned, thus demonstrating to his satisfaction that perceptions entirely devoid of emotions may give rise to the reflex. Kläsi in 1912 pointed out that although other psychic processes besides emotional ones may cause a galvanometric deflection, a greater throw appears with emotional associations than with those which are not emotionally toned. Kuhne (1913) showed that normal unconscious impressions have a galvanic reaction and present an emotional tension larger than the same conscious impressions. This finding, Kuhne believes, is evidence in favor of the theory that unconscious states exist psychically, so far as emotions are concerned. Waller (6), in a study of the emotivity of a subject during a German air-raid, found that deflections of the galvanometer only occurred in response to noises which indicated real possibility of injury, *e.g.*, the increasing hum of aero-

planes. This would indicate that in such an environment, at least, a strong emotionally toned stimulus is necessary in order to evoke a psychogalvanic reflex.

Several studies have also been made as to the value of the psychogalvanic reflex in detecting so-called "emotional" subjects. Although these studies will be considered more fully under the heading of "Applications," it should be stated here that Washburn, Harding, Simons, and Tomlinson, using a group of thirty-three cheerful and thirty-four depressed subjects (judged introspectively and by the rating of three friends), found that the cheerful group of subjects produced greater galvanometer deflections than did the depressed group, although they found no difference in effect between pleasant and unpleasant associations. Washburn and Pisek, in a further investigation, found that there was no significant correlation between the deflection of the galvanometer and the subjects' report of the intensity of the emotion which was aroused. This finding is contrary to that of Wechsler (3). W. S. Brown, in an investigation to obtain evidence regarding the supposed emotional significance of the psychogalvanic reflex, obtained only negative results, but was able to show qualities which have an element of "will," in the sense of consciously directed activity, correlated most highly with the galvanic reflex, and that those qualities having a predominantly emotional aspect all have low correlations with the reflex. This indicates that the psychogalvanic reflex may be more closely connected with the conative tendencies than with emotions. Bartlett concludes that we must look to the complex orectic processes for an understanding of the psychogalvanic phenomenon rather than to conation or emotion alone.

Contrary to the finding of Wechsler (3), of Radecki (2), and of others, many experimenters have found that the psychogalvanic reflex may be elicited by sensations entirely devoid of emotion. For example, Starch found that habitual mental activity, when accompanied by automatic physical activity (recitation of multiplication tables), produces a large galvanometric deflection. Sidis (1), and Sidis and Nelson, found that all active psychophysiological processes, sensory and emotional, with the exception of purely ideational ones, are capable of producing a galvanometric deflection. That deep inspiration and expiration influence the psychogalvanic reflex, as does coughing and other disturbances of the normal respiratory movements, has already been noted.

Bijtel and vanIterson (1) have conducted a careful investigation

of the influence of various odors on the psychogalvanic reflex and have been able to show that sensation, *per se,* is capable of producing the reflex. These investigators were unable to find typical differences between odors, whether they were unpleasant, pleasant, or neutral, but found that as a rule, whenever the subject says he has a clear sensation, the galvanometric deflection is greater than when this clear sensation is absent. In a later article Bijtel and vanIterson (2), using various types of sensorial stimuli, found that in man the resistance of the skin diminishes with such stimuli in proportion to the actual strength of the sensation produced. Philippson and Menzerath (1) found also that there is an exaggeration of the electromotive force output following both sensory and psychic excitation. It is evident that these results obtained from purely sensory stimuli furnish weighty evidence against the theory that only affectively toned stimuli are capable of producing a psychogalvanic reflex.

Starch and Veraguth (2) are of the opinion that the reflex corresponds at least roughly with the actual strength of the stimulus which arouses it. Grünbaum (1), Radecki (2), and Philippson and Menzerath (1, 2), however, point out that repeated stimuli lose effect even though they are of constant intensity, thus indicating that it must be the subjective state aroused by the stimulus and not the intensity of the stimulus itself which conditions the deflection. Grünbaum (1) further points out that the reflex follows the usual rules of attention in adapting itself to repeated stimulation of constant intensity. This leads us to a consideration of the effect of attention, as such, on the psychogalvanic reflex. Tarchanoff, as early as 1890, found that all mental functions were psychogalvanically active, and that expectant attention, mental work, and simple sensory stimuli caused a deflection of the galvanometer. Binswanger was able to get no galvanometric deflections when the subject's attention was diverted from the stimulus. This he attributes not to a voluntary suppression of attention but to determined inhibition giving rise to another emotion. Gregor (2) repeated the work of Binswanger and obtained results clearly contradictory to those of the earlier investigator. By diverting their attention from the experiment Gregor found that the subjects were in no degree capable of influencing the reflex. Gregor (2) did find, however, that an insufficiency of attention affected the reflex.

Veraguth and Brunschweiler, in 1918, found that the psychogalvanic reflex may be elicited from anesthetic parts of the body providing that the stimulus is repeated frequently for a period of

time or that the subject knows that he is being stimulated. They conclude that the psychogalvanic reflex is a part of the physiological adjustment for attention which works indifferently whether for the anesthetic area or for the normal parts of the body. Ricksher and Jung believe that the reflex depends on the attention to the stimulus and the ability to associate it with other previous occurrences. Moravcsik states that if a subject is hypnotized and told that a part of his body is anesthetic, stimulation of this area will produce no galvanic deflection. Grünbaum (1) explains this result as due to the factor of the intensity of the attention of the hypnotized subject so that sensory stimulation may not reach the awareness of the subject. Gregor (1) was unable to get such consistent results under hypnosis and could not verify the findings of Moravcsik. Grünbaum (1) explains this disagreement on the basis of different concepts of suggestion which involve the reacting of the subject. Reacting attitude or set has been shown by Sticker to have some effect on the psychogalvanic reflex. Grünbaum (1), after reviewing the results of other experimenters, concludes that the greater the attention within limits, the more intense the deflections. His own experiments furnished added evidence to this view. Wechsler (3), unable to disregard the influence of attention on the reflex, conducted an experiment to see if he could not link up this factor with affection in order to preserve his theory that affection alone is capable of evoking the psychogalvanic reflex. That deflections occur most frequently, not when the subject is maintaining constant attention, but when he turns his attention from one thing to another, and assuming that the turning of one's attention is most likely accompanied by affective reactions, then, according to Wechsler, the psychogalvanic reflex is an index of affective tone.

The effect of mental work in the psychogalvanic reflex was first pointed out by Tarchanoff, who demonstrated that mental multiplication produces the reflex only when it requires effort. Binswanger was not able to produce a reflex when the stimulus was purely intellectual, *e.g.*, reading lectures, etc., while Veraguth (5) found that the reading of an uninteresting newspaper article produced only a weak reflex and the reading of an interesting article gave a large deflection. Peterson and Scripture report that all mental work was accompanied by some degree of deflection, although mental work is less effective than emotional stimuli. Starch shows that habitual mental activity is accompanied by very little change in the galvanometric readings, but that when this activity is accompanied by automatic physical

activity (recitation of multiplication tables aloud), the reflex is marked. Starch also points out that voluntary mental activity produces a larger reflex than does automatic mental activity. Gregor (1) demonstrated the psychogalvanic reflex easily with intellectual work which was difficult for the subject. Philippson and Menzerath (2) and Moravcsik agree that mental work causes deflections which are not so pronounced as those given by emotions. These investigators therefore conclude that the mental effort involved in the intellectual work is that which influences the reflex. Gregor and Gorn, in 1913, made a study of the relationship between intellectual development and the form and size of the reflex, but found no significant correlation. Miss M. D. Waller found that intellectual efficiency is in some degree associated with higher nervous sensitivity as measured by the electrical emotive response for different stimuli. Miss Waller's work has been invalidated, both from the fact that she judges intellectual efficiency entirely on the basis of a single one hour physics examination and, as Jefferson pointed out, from inadequate statistical treatment of her results.

Prideaux(1) states that the reactions in subjects of poor intellect, as evidenced by their low scholarship at school, are rarely as marked as in intellectual subjects. Before any reliable decision can be made on this point, there must be further experimental work done under more scientific conditions.

The influence of volition on the psychogalvanic reflex is a problem which has interested several investigators. Binswanger reports that one of his subjects, believing that the galvanometer movements were due to suggestion, resolved not to give any attention to the experiment but to react as rapidly as possible. The result showed that either the speed of the reaction was greater or the duration was shorter and all psychogalvanic manifestations were absent. Binswanger attributes this, not to a voluntary suppression of attention, but to determined inhibitions giving rise to other emotions. Peterson (1) states that the psychogalvanic reflex is beyond the control of the will, but offers no experimental evidence to uphold his claim. Radecki (2) found that voluntary effort in a few isolated cases had an inhibiting influence on the reflex, due probably to respiratory changes. Abramowski states that his results clearly show a much more pronounced galvanometric swing when no effort was made to inhibit the reflex, and that when an effort is made to inhibit the reaction either a very feeble swing or none at all results. His subjects could either inhibit the reaction by thinking of something else or by preparing themselves for the stimula-

tion which was to be given. Gregor (1) invited his subjects to divert their attention to some other activity while the experiment was being conducted, but despite their lack of attention the psychogalvanic reactions of the subjects were not influenced in any way. Both W. Albrecht and McCowan agree with Gregor (1) in believing that the psychogalvanic reflex is an inevitable response which can in no way be influenced by the will of the subject. Grünbaum (1) reports that Pui Fontaine, in 1878, observed the voluntary production of the psychogalvanic reflex, but neither Radecki (2) nor Grünbaum could confirm this. Finally Stevanovic, in 1927, found that although conation is objectively indicated by bodily changes registered by the psychogalvanic reflex, volition gives no evidence of being accompanied by such changes.

The most outstanding point which is gained from this review of the psychological factors which may influence the reflex is the great divergence of opinion as to the exact effects of many of the psychological factors. The reviewers believe that most of this divergence of opinion may be traced to unscientific methodology or to a lack of knowledge on the part of the experimenter of the physical nature of the psychogalvanic reflex itself.

VII. Applications of the Psychogalvanic Reflex

A. Individual differences.—Radecki (2) seems to be the first investigator who has specifically mentioned experiments on individual differences as judged by the psychogalvanic reflex. His results show that any comparative use of the psychogalvanic reflex is impossible if it is to serve as a criterion for classifying subjects as to types and psychical point of view, but that it may be used to show the sensitivity of types which have already been established. Farmer and Chambers are of the opinion that the reflex is not a reliable means for measuring differences between individuals but that it can be used for group differentiation. Wechsler (4) attempted to discover by the use of the psychogalvanic reflex whether or not there was any such thing as general emotivity. Using a number of different types of affective stimuli, it was shown that no subject reacted in an emotional way to all affective stimuli, but that there was some evidence in favor of the view that individuals tend to be "specifically" rather than "generally" emotional. W. S. Brown has conducted a very interesting experiment with the reflex in conjunction with estimates of character qualities, the results of which show that there is no connection

between the psychogalvanic reflex and emotional tendencies as judged by two teachers who had all of the subjects in their classes. The author points out that the estimates of the character were uncertain because the subjects were observed only during school hours, and suggests that the experiment be repeated with students in a boarding school or residential college where more reliable character judgments may be obtained. M. F. Washburn *et al.*, (1, 2, 3) have published some interesting results from studies of individual differences in relation to the psychogalvanic reflex. The results show that (1) a cheerful group of subjects show greater galvanometer deflections than the depressed group; (2) the subjects who are rated as emotional tend to show greater galvanometric deflections when recalling emotional situations than do those who are rated as calm; (3) the amount of deflections of a galvanometer attached to the subject's hands correlates with both the degree of emotionality of the subject and the intensity of the revived emotion as introspectively reported; and (4) the galvanometer seems to be a reliable way of separating an emotional group from a calm group. The above types were picked on a point system by introspective judgment plus the judgments of three friends.

Syz (1), from a study of the psychogalvanic reactions of sixty-four students, concludes that the psychogalvanic reflex may be used as an indicator of characteristic features of the emotional make-up of groups of individuals and in a lesser degree of single individuals. Waller and Kojima found that there was no difference in the reflex of a Japanese subject as compared to an English subject.

B. Association experiments and the psychogalvanic reflex.— Veraguth (5) found that the recalling to memory of situations which at the time of their happening had strong affective tone had the effect of increasing the galvanometer deflections. Philippson and Menzerath (2) report the same phenomenon. Veraguth and Clotta were perhaps the first experimenters to point out the relationship between the psychogalvanic reflex and reaction time in word association. They found that in general long verbal reaction times correspond to large galvanometric deflections. Jung, in 1907, found that an increase in the psychogalvanic deflection when a stimulus word is given usually is an index of a hidden complex. Peterson and Jung found that reaction time and the psychogalvanic reflex were in some cases parallel and in others not, and so conclude that the reflex shows only acute affective states. Peterson (1) reports that in a word association test whenever a stimulus word strikes an emotional complex the result is

sure to be recorded by the galvanometer in a deflection directly proportional to the degree of the emotion aroused. Nunberg, in 1910, found that in association experiments there is a series of changes of the psychomotor mechanism which vary from the normal state, viz., breathing changes, which affect the psychogalvanic reaction. Menzerath believes that the psychogalvanic reflex, after it is perfected, shows some promise of being a good method to use in word association experiments. W. W. Smith (2) considers that for quantitative work the galvanometric deflection is superior to measurements of association-time, because it brings out better the differences existing in the affective value of different words. McCowan believes that reaction time and the psychogalvanic reaction, simultaneously obtained, can give valuable information in word association tests. Thouless, Pear, and Ikin, in 1924, used the psychogalvanic reaction in conjunction with dream analysis. Although these experimenters were able to get no reliable results, they have opened a field of investigation well worth considering. They suggest the use of the psychogalvanic reflex as a method of finding out whether a blank in free association is due to repression or to genuine absence of cognitive content. Although the galvanic phenomenon promises to be of some aid in free association experiments, it is faced by the difficulty that a stimulus word under the condition of the experiment may acquire emotional significance merely because it is part of the experiment.

C. Clinical applications.—On the basis of the results obtained with the galvanometer in word association experiments several investigators have attempted the use of the psychogalvanic reflex in psychoanalysis. W. W. Smith (1) has shown the value of the reflex for discovering hidden complexes, and therefore recommends it. Radecki (2) believes that the psychogalvanic reflex can be used for analyzing as well as the word association test of Jung. Other investigators who have worked in this field include Veraguth (5), Binswanger, Prince and Peterson (1, 2), Aptekmann, Litwer, and Lahy.

A second application of the reflex has been found in the field of mental disorders. Vigouroux (4), in 1888, found that in regions affected by local anesthesias the electrical resistance of the body is greater, and therefore suggested that resistance might furnish diagnostic evidences in cases of hysterical anesthesia, Graves' disease, etc. Tarchanoff, although he reports no actual experimentation on the subject, suggested that there is probably a deviation from the normal skin current in cases of infection and nervous diseases. Sticker, in 1897, observed that in cases of stupid and hysterical persons, the

spontaneous galvanometric fluctuations were far greater than those due to stimulation. Estorc found a divergence from the normal in the polarization rate in hysterical subjects. Veraguth (5) found that patients suffering from local anesthesias gave no response when an affected area was stimulated, although the patients could see what stimulus was being applied. He further points out that hysterical patients show a disproportion between their subjective and objective reactions, and therefore he regards the psychogalvanic reaction as a reliable means of distinguishing between organic and hysterical anesthesia. Prince and Peterson were able to get normal galvanic reactions with tactile stimulation from patients suffering with dissociated (hysterical) anesthesia although the stimuli were not consciously perceived by the patients.

Wiersma has been able to differentiate organic from functional deafness by means of the reflex plus changes in blood volume as determined by the plethysmograph. Zimmern and Logre (1) and vanIterson have described similar results. W. Albrecht states that he has been able to separate functional from organic hearing disturbances with the aid of the reflex. He also reports that in cases where patients feigned deafness the deceit was discovered and the auditory acuity of the patients ascertained in 44 out of 45 cases. Goebel believes that the psychogalvanic reflex is a very good means of throwing more light on the mechanics of mental disturbances, but states that although it is a valuable diagnostic aid, this reaction alone, without other checks, cannot be looked upon as unconditionally reliable. Veraguth and Brunschweiler have indicated that the reflex is not, after all, a sure method of differentiating organic from functional disorders, by showing that in an individual who normally has a weak psychogalvanic reaction due to organic lesions we may obtain a marked reflex by repeated stimulation, and that at times the reflex may appear without repeated stimulation. These authors conclude that the psychogalvanic reflex cannot be used as a differential diagnosis of deception or hysterical simulation. This is in direct disagreement with Gregor and Gorn, and Prideaux (2), who found that the galvanic reflex may be used in clinics as a method of detecting simulation in suspicious cases. Binswanger insists that the reflex is not a reliable measure because inattention to the stimulus will cause the disappearance of the reflex even in normal subjects.

Ricksher and Jung found that although normal psychogalvanic reactions vary greatly in different individuals, they are as a rule always greater than pathological reactions. They point out that in

depression and stupor the galvanic reactions are weak because of inattention and inhibitions, while in alcoholism and in the euphoric stage of paresis the reactions are exaggerated because of a greater excitability. Peterson and Jung report that hebephrenic patients give normal psychogalvanic reactions but that in catatonic forms of dementia precox the latent period of the reflex is comparatively long and the reflex itself is extremely weak. They also found that in chronic catatonia only the most severe stimuli have any effect, while patients suffering from acute catatonia give no galvanic reaction. Wells and Forbes found that the reflex occurred in an individual with catatonic stupor. C. P. Richter (2) states that catatonic stupor patients show normal reflex indicating that they have great nervous activity which is somehow inhibited from affecting the muscles and consequently there is muscular relaxation. McCowan found that affectivity varies in different cases of dementia precox, but that all hebephrenic patients who came to his attention showed increased affectivity and larger than normal psychogalvanic reflexes. Syz (1) reports that the average electrical resistance in catatonic stupor patients is more than twice as high as it is in normal persons. Paranoid schizophrenics have a high average resistance, but this resistance shows an excessive drop during the experimentation. In fifteen depressives, Syz found that the average resistance increased greatly and remained constant throughout the experiment.

Gregor and Gorn report that epileptics give very uncertain results, while patients suffering from arteriosclerosis give no reflex. Senile dements whose intellectual processes are affected, but who are otherwise normal, gave normal psychogalvanic reactions. Prideaux (2) found that conversion hysterics gave small galvanic reactions, while anxiety hysterics give large ones.

Abbot and Wells, working with manic-depressive patients, report that the latent periods were longer than for normal subjects, and suggest that the retardation lies in a lessened complexity of the associations formed or in a slower and more feeble conversion of these associations into their motor expressions. Godefroy (2) was able to record the continuous emotional agitations which characterized different periods of exophthalmic goiter and to show that as the patients improve their psychogalvanic reactions approach more and more nearly those obtained from normal persons. Bumke has suggested other clinical applications of the reflex.

In working with feebleminded subjects, Gregor and Gorn found that congenital idiots have very large psychogalvanic reactions, but

of the normal type, and that one border-line patient showed a normal reaction, while three cases of imbecility showed small reactions. Prideaux (2) reports that twelve of seventeen idiots gave no psychogalvanic reaction although they certainly perceived the stimulus. Claparède found that idiots give a smaller psychogalvanic reflex than do people of normal intelligence. Haymann has also noted the difference in the reflex in normal and feebleminded subjects.

VIII. Miscellaneous

A. Hypnosis.—E. K. Müller (2), in 1904, seems to have been the first investigator to observe changes in the electrical phenomena of the skin of a subject under hypnosis. Using only one subject, Müller says that at first and for a long time the conductivity held constant (as in sleep). After this followed a jerky augmentation of resistance. Moravcsik states that a subject under hypnosis gave psychogalvanic reactions to stimuli which could not have been directly perceived, *e.g.*, visual stimuli not in the direct field of vision. He claims that the galvanic response can be elicited or inhibited by suggestion. Grünbaum (1) explains this latter phenomenon as due to the factor of intensity of the attention of the hypnotized subject so that sensory stimulation could not reach his consciousness. Georgi also found that in the hypnotic state the psychogalvanic reflex can be inhibited by suggestion. Peiper, working with children, reports that the reflex is maintained during hypnosis.

Prince and Peterson (2) have reported an interesting psychogalvanic experiment done under hypnosis on one of Prince's multiple personality patients, with three distinct personalities. Personality A, who was mnesic with respect to C when under hypnosis, gave galvanometric deflections to stimulus words which were only meaningful to C. Other words which were "indifferent" for both A and C gave no deflections. Prince and Peterson interpret this result as proof that any conscious experience or memory may, in spite of the subject's total amnesia for it, continue to exist co-consciously and provoke a psychogalvanic response identical with that produced by any conscious experience.

B. The psychogalvanic reflex in children.—Peiper, in 1924, found that no psychogalvanic reflex could be obtained from infants under one year of age, although they showed other bodily reactions to stimuli. In children who have passed the stage of infancy the reflex occurs as in adults. Peiper also found that in sleeping children the reflex is dependent upon the soundness of sleep. H. E. Jones, con-

trary to Peiper, found that the psychogalvanic reflex could be elicited in infants less than six months old by pain, withdrawal of nursing bottle, restraint, and loud sounds. The divergence in the results of these two experimenters indicates that further research is desirable in this field.

C. Practical applications.—Waller (5) has used the psychogalvanic reflex as a means of determining the fitness of men for air service. He considers men who show little emotivity better fit for aviation than those who are emotional. Waller also points out that members of literary, artistic, and scientific professions give relatively high responses to imaginary excitations, while manual workers and privates in the army respond principally to real stimuli.

Linde, in a recently published article, states that the judgment of the goodness of jokes, when plotted against the galvanometer deviation of the psychogalvanic reflex, has the form of the logarithmic Weber-Fechner curve.

D. The psychogalvanic reflex in animals.—That the galvanic reflex could be elicited in animals has long been recognized. Veraguth (5), in 1909, found that it occurred in dogs, cats, and toads, while Erbs has studied the reflex in the horse and the dog. Hara states that the psychogalvanic reflex was obtained only once in six curarized dogs, and *that* with an auditory stimulus. The reflex, however, was obtained in all but one of ten curarized cats with visual, auditory, and tactile stimuli. Strohl, Libert, and Iodka (5) found that the counter-electromotive force is higher in the dog than in man, and that the skin plays a preponderant rôle in the appearance of this counter-electromotive force.

Gopalaswami (2, 3) has done some interesting experimental work with the psychogalvanic reflex in monkeys. He found that the monkey shows larger reflexes when impulsive acts are suppressed than when acts, even of a nocuous variety, are carried out. This tends to support the theory that the reflex is primarily a measure of the inhibitive control over the expression of emotional excitement.

E. Summaries and reviews.—The following authors have published reviews of the literature of the psychogalvanic reflex: Dunlap (1, 3), Prideaux (1), Sutherland, Grünbaum, and Woodrow. Farmer and Chambers, Radecki (2), and Wechsler (3) have given extensive summaries of various aspects of the literature in connection with their own experimental work.

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NOTES AND NEWS

At the University of Iowa on October 10th, there was a celebration in honor of Professor Carl E. Seashore in commemoration of his completion of twenty-five years of service as professor of psychology. The chief event was the presentation of a lifesize portrait in oil of Dr. Seashore done by Mrs. Mildred M. Pelzer, a local artist. Dr. R. H. Sylvester, head of the department of psychology at Drake University, made the presentation on behalf of Dr. Seashore's former students. The University was represented by President Jessup. More than a hundred friends and former students of Dr. Seashore were present including psychologists from Cornell College, Coe College, Iowa State Teachers College, Iowa State College of Agriculture and Mechanical Arts and Drake University. A moving picture of Dr. Seashore was shown and he made a very brilliant reply after the presentation of the portrait.

Dr. Milton Metfessel, for three years National Research Fellow in psychology, has been appointed associate professor of psychology and phonetics in the State University of Iowa.

Professor E. L. Thorndike, of Teachers College, Columbia University, will give twelve lectures on the Messenger Foundation, Cornell University, on the subject of "The General Field of Psychology."

Graduate students of psychology may subscribe to *Psychological Abstracts* at $5.00 a year, instead of the regular rate of $6.00. Subscriptions should be accompanied by a certification of their graduate student status from a member of the American Psychological Association, and sent to the Business Office of Psychological Abstracts, Princeton, N. J.